

# TUMOURS INVOLVING THE CAUDA EQUINA : A REVIEW OF THEIR CLINICAL FEATURES AND DIFFERENTIAL DIAGNOSIS.\*

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I.	INTRODUCTION .. .. .	111
II.	THE SYMPTOMS AND SIGNS OF LESIONS OF THE CAUDA EQUINA .. ..	113
III.	THE CLINICAL COURSE OF CAUDAL TUMOURS .. .. .	116
IV.	THE SYMPTOMS OF CAUDAL TUMOURS .. .. .	118
V.	THE PHYSICAL SIGNS OF CAUDAL TUMOURS—	
	(1) General Abnormalities .. .. .	124
	(2) Changes in Sensation .. .. .	124
	(3) Variations in the Motor Functions .. .. .	126
	(4) Variations in the Reflexes .. .. .	127
	(5) Trophic Disturbances .. .. .	129
	(6) X-ray Examination .. .. .	129
	(7) The Results of Lumbar Puncture .. .. .	130
VI.	THE LOCALISATION OF CAUDAL TUMOURS .. .. .	132
VII.	DIAGNOSIS AND DIFFERENTIAL DIAGNOSIS .. .. .	135
VIII.	DISCUSSION .. .. .	138
IX.	SUMMARY AND CONCLUSIONS .. .. .	141
X.	REFERENCES .. .. .	142

## I.—INTRODUCTION.

A GENERAL survey of the material available in the literature at once draws attention to the fact that it is only in the late and hopeless stages of cauda equina tumours that the classical clinical picture of a lesion of the cauda equina or even a collection of symptoms and signs similar to that produced by a traumatic lesion is encountered. An attempt has therefore been made to examine in detail the reports of cases available and to correlate the clinical and pathological findings with the diagnosis made at operation or at autopsy as well as with the localisation of the tumour itself. Such a review has naturally involved the consideration of the differential diagnosis of caudal tumours and this aspect of the subject has been dealt with in addition.

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The early recognition and localisation of tumours of the cauda equina are of paramount importance. In early cases successful removal and complete functional recovery are often possible, while in long-standing cases the chances of successful removal are much lessened and even when it is possible functional recovery is often infinitesimal.

The absolute frequency of tumours of the cauda equina is difficult to determine. It is possible to consider their frequency only in relation to that of spinal tumours as a whole. In a statistical study Steinke<sup>1</sup> found 30 cauda equina tumours in a series of 330 spinal tumours, an incidence of approximately 9 per cent. Elsberg<sup>2</sup> described 12 cases among 81 cases of spinal tumours, a frequency of 15 per cent. Parker<sup>3</sup> described 8 cases among 33 cases of spinal tumour, a frequency of 24 per cent. Such a high incidence was, however, rather counteracted by the occurrence among 85 cases of spinal tumour reported from the Mayo Clinic of only 3 cases with lesions of the cauda equina, only one of which proved to be a tumour. In general, it would appear from the statistics of the cases reported in the literature that approximately one in ten of spinal tumours affects the cauda equina.

The prognosis of cauda equina tumours is difficult to assess, more particularly as in such cases two separate factors must be considered, viz., (1) the chances of removal of the tumour, and (2) the prospects of functional recovery. An examination of the case records in the literature, however, makes it perfectly clear that the prognosis in relation to both factors is much improved if detailed investigation and surgical intervention are undertaken, in the one case as soon as a suspicious symptom appears and in the other as soon as unequivocal evidence of the presence of such a lesion is available. Tumours of the cauda equina are difficult to remove completely because of the number of nerve roots in that region, and because of the fact that the roots may pass through or surround the tumour, making careful dissection necessary for its removal. Of the 30 cases referred to by Steinke 13 or 43·3 per cent. were greatly improved and 14 or 46·6 per cent. died. Complete functional recovery occurred in 5 cases or 41·6 per cent. of Ott and Adson's<sup>4,5</sup> cases, a figure which probably represents the prospects of complete recovery in cases in which radical treatment is undertaken at a moderate period after the onset of symptoms. Lennalm<sup>6</sup> reported 15 cases in 3 of which a good result was obtained by operation, Cassirer<sup>7</sup> cured 2 cases out of 24 reported, Ehrenberg<sup>8</sup> had good results in 2 cases out of 3; Landelius<sup>9</sup> described 3 successful cases diagnosed before the onset of pareses or disturbances of sensation; while Karl Grosz<sup>10</sup> reported poor results in two cases of tumour of the cauda equina operated on late. Generally, with the exception of the more malignant tumours, good results have followed surgical intervention undertaken before definite pareses, pronounced sensory changes or serious disturbances of the sphincters appeared or in cases in which they were of short duration. The importance of the sphincters as a guide to the prospects of successful treatment will be dealt with at a later stage.

The type of tumour present would appear to have a considerable influence upon the prognosis, those which can be removed with as little injury as possible to important structures offering better prospects of success than those in which there has been extensive involvement of the nerve roots and of the conus medullaris.

## II.—THE SYMPTOMS AND SIGNS OF LESIONS OF THE CAUDA EQUINA.

The classical descriptions of the clinical features of a cauda equina lesion are based upon a fairly extensive lesion, are applied in regard to some features to lower caudal lesions and in others to higher caudal lesions, and confuse the disturbances of the bladder and other functions produced by lesions of the sacral nerve roots and by those of the conus medullaris. Further, they presume the involvement of all the functions concerned and are, in consequence, scarcely applicable to the elucidation of cases of caudal tumours in which the functions may be affected in what appears to be a haphazard manner.

A more satisfactory working basis has been provided by Roussy and Lhermitte<sup>11</sup>, who systematised the clinical features of traumatic lesions of the cauda equina in a study of the effects of gunshot wounds in that region. They differentiated five clinical syndromes :—

- (1) a total syndrome, corresponding to lesions high up at the level of the second lumbar vertebra ;
- (2) a lumbosacral syndrome, from lesions in the region of the lumbosacral articulation ;
- (3) a sacral syndrome, due to lesions which are chiefly sacral ;
- (4) a hemicaudal syndrome from lesions which attack one half of the cauda equina ; and
- (5) a radicular syndrome, due to a lesion involving one or more of the nerve roots.

The total syndrome includes paralysis of the bladder and rectum, severe pain in the region of the sciatic nerve and in the sacral and perineal regions, loss of all reflexes in the lower limbs and anæsthesia of the whole of both lower limbs together with complete paralysis of all movements. It is based on a complete lesion of the cauda equina, involving all the lumbar and sacral roots below the exit of the second lumbar. The lumbosacral syndrome is the result of involvement of the fifth lumbar and all the sacral roots, and is described by Roussy and Lhermitte as the most common clinical type. It is characterised chiefly by paralysis of all the muscles supplied by the sciatic nerve on both sides, root pains in those areas, impairment of sensation in the distribution of the nerve roots involved, vesical and rectal troubles and absence of the ankle jerks. In a much less complete form it is a fairly common clinical picture in cases of caudal tumour. The sacral syndrome is characterised by root pains, vesical and rectal disturbances, saddle-shaped anæsthesia with sometimes impairment of sensation in a strip down the back of both thighs,

and the complete absence of motor troubles. It is described briefly as the ano-genital-vesical syndrome. The hemicaudal syndrome is characterised by the extreme preponderance of motor, sensory and reflex changes on one side, and is such as would be produced by a wound to one side of the middle line. Sphincter disturbances are usually transitory but occasionally they persist. The radicular syndrome varies in its details according to the root or roots affected. Monoplegia or paraplegia may appear after the injury and disappear; while only local limitation of movement, anaesthesia more or less in root areas, and various degrees of dissociation of sensation may remain. It is a clinical picture which resembles very closely that of caudal tumours in the early or intermediate stages when treatment can be carried out most effectively.

These syndromes, however, are based on lesions which are more or less acute and complete in themselves. In every case the initial damage is probably the maximum produced and the final clinical picture may be that of a definite, local circumscribed lesion. The syndromes are not applicable in toto to the study of lesions which arise insidiously and increase in their size and effect over a short or a long period. They take no account, moreover, of the peculiar features of caudal tumours in that they may damage some functions while others are unaffected. It would appear, however, that the hemicaudal and radicular syndromes might be applied with success to the study of caudal tumours in their earlier stages, while it is evident that the total and lumbosacral syndromes might be encountered fairly often in advanced and hopeless cases.

An attempt has been made to classify 69 cases of caudal tumour on the basis of the syndromes of Roussy and Lhermitte. While it was usually possible to fix the upper level of the lesion from the symptoms and physical signs and thus roughly classify the cases, it was nevertheless evident that, with the exception of the hemicaudal and radicular syndromes, the syndromes could not serve as a reliable working basis for the study of tumours of the cauda equina. Occasionally, in an advanced case the complete picture of the total syndrome was present but otherwise no syndrome could be regarded as complete. One or more important features of the syndrome were missing and no general conclusion could be reached as to how the clinical picture depended upon the localisation, extent and nature of the tumour. The only conclusion possible was that, when all the symptoms and signs were carefully considered, that produced by a lesion at the highest level probably gave an indication of the upper level of the tumour. Otherwise, the tumours appeared to affect certain nerve roots, leave others unaffected, interfere with some functions and leave others quite normal according to no obvious rule.

Wolfsohn and Morrissey<sup>12</sup> mention the possibility of applying the syndromes of Roussy and Lhermitte to the study of chronic lesions such as tumours and content themselves with stating that, though the syndromes are never so definite, they are sometimes helpful. With some reservations we can agree with this conclusion.

A study of the syndrome classification based upon the clinical evidence at the time of operation compared with that based on the pathological evidence reveals some interesting results. In the 'total' syndrome, particularly, the clinical picture was in nearly every case incomplete and in at least one-third of the cases some important clinical feature was missing. Clinically, the syndrome appeared to be 'total' in 64 per cent. of cases, 'lumbosacral' in 18 per cent., and 'sacral,' 'hemicaudal' and 'radicular' in 6 per cent. each. As was to be expected, in every case in which the clinical syndrome was of the 'total' type, even though incomplete, the pathological evidence confirmed the classification. In one half of the cases in which the syndrome appeared to be of the 'lumbosacral' type the lesion was of the 'total' type pathologically. An interesting conclusion is evident on comparing the frequency of the 'hemicaudal' and 'radicular' syndromes in the early stages of the illness with the frequency at the time of operation. In at least 91 per cent. of cases the clinical picture was of the 'hemicaudal' or 'radicular' type from a comparatively early stage, and in at least 61 per cent. of cases it was definitely of the 'radicular' type. This comparison at once suggests that, if the treatment of tumours of the cauda equina is to be satisfactory, the whole conception of the symptomatology must change so as to permit of complete investigation and treatment in the earliest stages. If that is to be so the usually accepted clinical picture of caudal tumours and even the syndromes of Roussy and Lhermitte must be put to one side as a basis for the study of tumours of the cauda equina.

The symptomatology of lesions of the cauda equina as applied to tumours in that region has been reviewed by Parker<sup>3</sup>, Péron<sup>13,14</sup>, Spiller<sup>15</sup> and others. The first emphasised the difficulty of studying tumours in this region on the basis of the recognised clinical syndromes. He found that tumours at widely separated levels may produce almost identical symptoms and physical signs and that, in some cases, the determination of the extent and position of the tumour seemed to be impossible. Every case appeared to differ. The type of tumour influenced the course, symptomatology and physical signs—the more malignant tumours producing a more rapid clinical course and more diffuse signs, while the slow-growing tumour produced a long course and clear-cut physical signs. An important source of difficulty was the fact that the sacral canal was wide and that a tumour might grow there for a long period without symptoms or physical signs. He reviewed the symptomatology and drew attention to certain clinical features which he had found to be of great value in diagnosis.

Spiller<sup>15</sup> reviewed the subject of tumours of the cauda equina up to 1908 and in particular stressed their differential diagnosis; while more recently Elsberg<sup>2</sup> has drawn attention to certain unusual features of tumours in that region. Apart from these the literature on tumours of the cauda equina has been confined to a review of individual cases and the discussion of their differ-

ential diagnosis. Exceptions have been a comprehensive paper by Ott and Adson<sup>4</sup> in which the symptomatology, diagnosis, localisation, pathology and the results of surgical treatment were discussed in detail, and another by Elsberg and Constable<sup>16</sup> in which the differential diagnosis of caudal tumours from neuritis of the caudal roots was considered.

### III.—THE CLINICAL COURSE.

The duration of the clinical course of caudal tumours before coming under surgical treatment varies considerably with the nature of the tumour, the structures involved, the presence or absence of complications and the period of the clinical course at which the patient was first subjected to a thorough investigation. Of the cases referred to the average duration was about four years, the longest being 20 years and the shortest three months. It was particularly noticeable, however, that with the improvement in the knowledge of the initial symptoms and the use of special methods of investigation in those cases in which the initial symptoms were suggestive, the average duration of the clinical course before the patient came under effective treatment was much reduced. There always remain, however, numerous cases which have escaped investigation for several years because the condition has been regarded as sciatica, lumbago and other conditions. The duration of the clinical history varied considerably in the different series reported. The average duration of Spiller's cases was less than one year, that of Parker's three years, that of Elsberg's five and a half years, and that of Ott and Adson's a little over six years. The circumstances of practice and the material available vary so much that it is impossible to draw any general conclusion from these figures, excepting that a caudal tumour may produce a serious clinical picture in three months or twenty years from the onset according to the character of the tumour and the structures involved.

A study of case-records to determine the most important of the initial symptoms reveals the following information. *Pain* is an important initial symptom in 90 per cent., while in 10 per cent. it is not present as an initial symptom but appears at a later stage. In one case, that of Volhard<sup>17</sup>, erroneously referred to as the only painless caudal tumour in the literature, the subsequent pain was rather of the nature of a feeling of pressure over the sacrum. In 70 per cent. *pain in the back* is the important initial symptom. It appears alone in 23 per cent., is associated with pain down one sciatic nerve in 10 per cent., and with pain down both sciatic nerves in 10 per cent. In 18 per cent. the pain in the legs develops at a later stage, so that initial pain in the back is associated with pain radiating into one or both legs, and chiefly into the area of supply of the sciatic nerve, in 36 per cent. *Pain in one or both legs*, either alone or associated with other symptoms, is the initial symptom in 61 per cent. It appears alone in one leg as 'sciatica' in 9.5 per cent., and alone in both legs as 'double sciatica' in 8 per cent. Occasionally, the pain in the leg or legs is confined to a portion of a segmental root area. In 1.5 per cent.

it appears in the foot alone ; in 3 per cent. it appears first in the hip in the region of the great trochanter ; and in 3 per cent. it appears in one gluteal region. In 3 per cent. it appears first in the back and one groin. *Pain in the lower part of the anterior abdominal wall* together with other symptoms is an initial symptom in 6 per cent. of cases, weakness of the legs appears first in 6 per cent. of cases, and interference with the functions of the bladder and bowel in 4.5 per cent. Unusual initial symptoms are pain in the rectum in 1.5 per cent., cramps in the legs in 1.5 per cent., and pain in the distribution of one anterior crural nerve in 3 per cent. Lower abdominal pain and interference with the functions of the bladder are initial symptoms in cases in which the tumour is at a high level and in which there is obviously some involvement of the conus medullaris or spinal cord. The importance of pain in the symptomatology and the relation of its situation to involvement of individual roots will be discussed at a later stage.

The clinical course of the condition varies considerably. Wolfsohn and Morrissey<sup>12</sup> describe the course as a rapid acute phase passing into a chronic or intermittent phase as regards the symptoms. The intermittency of symptoms in the early stages of caudal tumours, mentioned also by Beriel<sup>18</sup> and illustrated by many cases in the literature, is often a serious source of error in diagnosis. In about 25 per cent. of the cases symptoms appear for a short time and then disappear. This is particularly so when pain is the initial symptom. Sciatica appears on one side, is relieved and later reappears either on the same or on the other side. It is apparent, therefore, that the disappearance of the initial symptom and particularly of pain does not render a complete investigation of the patient unnecessary.

Péron<sup>14</sup> describes the characteristic clinical picture in three phases. The 'période de début' he ascribes to the early accident of irritation of nerve roots and the consequent production of root pains. At some time in their clinical course over 90 per cent. of cases show this clinical feature. The 'période de début' is characterised chiefly by root pains. Péron states that bladder symptoms often appear during this phase, but in doing so he is probably confusing the initial symptoms of caudal and of conus tumours. An onset with intestinal and rectal troubles is comparatively rare. The 'période de début' is the phase of diagnostic errors but none the less the phase during which the presence of a caudal tumour must be suspected and a complete investigation made if treatment is to be successful. Péron names his second phase the 'période d'état,' that during which definite symptoms appear and frank physical signs are present. These changes are one or all of : motor abnormalities including local or general flaccid paralysis and atrophy with variation in the corresponding reflexes, subjective and objective sensory changes, abnormalities of the pelvic viscera and of the sphincters, and trophic changes. It is the phase during which, on a complete physical examination, the diagnosis may be reasonably certain. The final phase described by Péron is that in which

the primary condition is so obscured by visceral and sphincteric disturbances that the patient's condition is more or less hopeless.

In general Péron's classification may be accepted as the basis of a working classification. The period of onset might be regarded as characterised by the symptoms described as initial symptoms. It is the period at which errors in diagnosis are certain to occur if the investigation stops at the stage of a neurological examination, the period at which special methods of investigation are necessary to make a complete diagnosis. The ease with which the initial symptoms are ascribed to conditions other than caudal tumours is largely responsible for the investigation being curtailed, but the success which has followed a complete investigation even in the earliest stages in cases described by Bennett<sup>19</sup>, Wolfsohn and Morrissey<sup>12</sup>, and by Cushing and Ayer<sup>20</sup> shows how necessary it is to carry out such investigations when the symptoms suggest a caudal lesion. In place of the term 'période de début' used by Péron this phase might be termed the 'phase of special investigations.' During the second phase in which definite symptoms and physical signs are present special methods of investigation may be necessary but are not essential for a working diagnosis. During this phase such investigations are most often needed for confirmation of the diagnosis and the exact localisation of the lesion. In the final phase, that of complications, the condition of the patient is usually hopeless, but that it is not always so after satisfactory treatment of the complications is shown by a case reported by Cushing and Ayer.

#### IV.—THE SYMPTOMS OF CAUDAL TUMOURS.

The initial symptoms of caudal tumours and the importance of pain as a factor in the early stages of the clinical course have been dealt with above. The symptoms are now described in detail and their particular characteristics stressed. Until recently the only case on record of a tumour of the cauda equina which did not give rise to symptoms or physical signs was that reported by Spiller<sup>21</sup> of a lipoma of the filum terminale, but systematic examination of the cauda equina at autopsy has shown that such silent caudal tumours are not uncommon.

(1) *Pain*.—Pain is the initial symptom in over 90 per cent. of cases of caudal tumour. In the remaining 10 per cent. it appears at a comparatively early stage of the clinical course. Volhard's<sup>17</sup> case which has been mentioned as being the only painless case in the literature was that of a patient who had fairly early a sense of pressure in the region of the sacrum. The time of appearance, localisation and distribution of the pain would appear to depend upon a series of factors such as the nature of the tumour, the rate of growth, the position of the tumour and particularly its antero-posterior relations to the roots of the cauda equina. It is apparent, however, that the last-named factor has a much greater influence upon the presence or absence of the objective sensory changes than upon the subjective sensory symptoms. Further, pain does not appear to be such an important symptom in cases in which a large soft



tumour fills up the greater part of the spinal canal as in those in which a small hard tumour is attached to the dura or to one of the nerve roots.

The position of the pain depends largely upon the caudal roots affected. In 79 per cent. of cases it appears first in the back, either in the lumbar or sacral region, and in 23 per cent. it never at any time appears elsewhere. In 10 per cent. it is associated with pain of the root type down one leg, and down both legs in a further 8 per cent. Eventually pain in both legs is associated with pain in the back in 36 per cent. of cases. It is evident from an examination of the case-records that pain in the back is in no way associated with involvement of the vertebræ by the tumour. Such an accident was comparatively uncommon in the records examined, whereas backache was an exceedingly common symptom. It is possible that the backache so common as an initial symptom may be a further manifestation of a nerve-root pain, but it is of little value in localisation because of the diffuse character of its distribution. In two-thirds of the cases in which it is present it appears in the lumbar region, and in the remaining one-third it appears in the sacro-iliac joint or in the sacral region. In the cases with lumbar pain the lesion was found to vary between the level of the fifth lumbar vertebra and that of the twelfth dorsal vertebra, the majority of them being towards the upper level. In the cases with lower back or sacral pain the lesion was in the lumbar region in one half and in the sacral region in one half. Spiller<sup>15</sup> states that the position of the pain in the back may sometimes be of value in localisation. From this review it is evident that the level of the pain in the back cannot be of great value clinically in fixing the level of the tumour. Such a pain is probably a referred pain from involvement of one or more of the caudal roots, or a local pain from involvement of the spinal meninges. In the former case it cannot always be certain that a nerve-root corresponding to the upper level of the tumour is involved. It might be supposed that the highest level at which the pain appears might help to fix the level of the lesion, but the vagueness with which pains in the back are usually described by the patient renders this almost impossible.

It is quite different, however, when the lower roots are involved and the pain is referred to the lower limbs. Pain in one or both legs is an initial symptom in 61 per cent. of cases. It appears alone in one leg as 'sciatica' in 9.5 per cent., and alone in both legs in 8 per cent. More often, however, it is associated with pain in the back. The common sequence is for pain to appear in the back or one lower limb and then to radiate into the other situation. The pain in the leg is usually referred down the back of the thigh and into the front or back of the leg. In some cases, at a later stage, it appears in the corresponding position in the other lower limb. In a few cases the pain appears in only a part of a segmental area, in the foot or in the hip. At first the pain is slight and intermittent and later becomes constant. Frequently it disappears for some months or even for a year and then reappears in the same situation in the same or in the other lower limb. The distribution of the pain is usually con-

fined to definite segmental areas, and frequently from its distribution the upper level at which irritation of the posterior nerve roots occurs can be estimated. When the lower sacral roots are involved the pain is referred to one gluteal region, to the back of one hip or to the perineum ; when the upper two sacral roots are involved, down the back of the thigh and leg ; and when the fifth lumbar root is involved it is referred to the front of the leg below the knee. In other cases pain is referred to the inner side of the knee, probably from involvement of the third and fourth lumbar root, and to the groin from involvement of the second lumbar root. In a few cases it is referred to the lower part of the anterior abdominal wall and occasionally to the iliac region.

The character of the pain and the conditions under which it occurs deserve some consideration. Generally, it has the characteristics of a root pain, but there are several important features in which it differs from a root pain occurring in lesions affecting the spinal cord and from that produced by a lesion of a peripheral nerve. The intermittency and the mild character of the pain in the early stages have already been referred to. It may appear during the later months of pregnancy and disappear after labour. Subsequently, it becomes severe and constant but even after it has been present in this form for a long period it may disappear and reappear only after a long interval. In one case the period of intermission was as long as seven years. The pain in the back is usually a dull ache and increases a little on movement of the back. Under such conditions the patient is often treated for lumbago. In some cases it is severe, has a burning, crushing character, and is referred to one or both sciatic nerve areas. Frequently there is a constant dull ache in the back and affected limb with acute exacerbations which the patient finds almost unbearable. Percussion of the spine, jarring of the head, stepping too firmly on the floor and sometimes moving the arm may cause an acute exacerbation. Coughing, straining and swallowing may aggravate the pain. In these respects the pain does not differ from ordinary root pains.

There appears to be a difference of opinion about the influence of movement upon the pain ; but the examination of a number of cases in which pain is present in the early stages only in the recumbent position and is completely absent even when walking many miles suggests that movement is not an aggravating factor, at least in the early stages. In two consecutive cases described by Parker<sup>3</sup> the pain was always worse in the recumbent position while in a further case reported by the same writer walking always relieved it. Parker further pointed out that in the early stages it was common for the patient to sit in a chair to get relief in preference to lying in bed, and stressed the fact that the pain associated with caudal tumours was usually relieved by movement. Lind and Lundstein<sup>22</sup> reported a case in which severe pain on the inner side of the thigh always became worse when going to sleep. In Wallgren's<sup>23</sup> case the pain was always worse at night, while in one of Wolfsohn and Morrissey's<sup>12</sup> cases the pain appeared only at night, increased in severity towards the morning and disappeared during the day. Bennett<sup>19</sup> described in

one case pain which was severe at night, and was present in the daytime only when the patient yawned or stooped. A similar contrast in the character of the pain has also been mentioned by Ehrenberg<sup>24</sup>, Volhard<sup>17</sup>, Wallgren<sup>23</sup> Lennalm<sup>6</sup>, and Schmoll<sup>25</sup>. Hammes<sup>26</sup> and Box<sup>27</sup> particularly stressed the fact that the recumbent position aggravated the pain, the patient described by the latter being unable to sit or to lie comfortably on account of pain in the lower part of the back. Viets<sup>28</sup> patient could sleep only in a chair, while Schmoll's patient was obliged to sit in a chair and rest his head on the side of the bed in order to get sleep. In their review of caudal tumours, Ott and Adson<sup>4</sup> stressed this contrast in the severity of the pain as an important factor in the differentiation of the pain due to irritation of the roots of the cauda equina from that of sciatica. Occasionally a case has been reported in which the pain has been aggravated by movement but nevertheless the greater part of the evidence goes to show that the pain of caudal irritation due to tumours is aggravated in the recumbent position and relieved in the erect position and by movement.

An interesting explanation of this variation has been offered by Wallgren, who has suggested that the contrast is due to the varying degree of tension upon the roots of the cauda equina in the two positions. His explanation is that in the recumbent position the normal lumbar lordosis is decreased, the lumbosacral canal is lengthened, and the tension thus put on the caudal roots already subjected to irritation is sufficient to lead to severe exacerbations of pain. Conversely, the erect position increases the lumbar lordosis, lessens the length of the spinal canal and the tension on the caudal roots and thus relieves the pain. There is, however, the possibility that in some cases the lessening of cortical control with the inducement of sleep is responsible in some measure for the onset of the pain at night. The onset of sleep has been noted as an important factor in those cases in which the nerve-roots have been subject to irritation because of osteoarthritis, as they passed through the intervertebral canals. Variation in the lumbar curve has of course no influence in such cases. Such a contrast may sometimes be of value in differentiating pain due to irritation of caudal roots inside the spinal canal in the vertical part of their course from that due to irritation of the nerve trunks as they pass through the intervertebral foramina—in fact, between an intraspinal and a spinal condition. The pain of sciatica is increased by movement and lessened by rest and the recumbent position, an observation in direct contrast with that usual in caudal lesions. The contrast with the root pains due to lesions of the spinal cord is not always evident.

Even though the area of supply of a lumbar or sacral nerve-root or roots has become completely anæsthetic, pain may continue to be felt there—a condition of anæsthesia dolorosa. In such cases a number of different sensations may be felt in the whole or part of the segmental area. The explanation probably is that, while the roots are so destroyed that sensations from the

periphery are conducted very poorly or not at all, the lesion still serves as a source of stimulation to the central fibres and the impulses so initiated are interpreted in different ways by the central mechanism.

(2) *Other spontaneous sensations*.—Pain is by far the commonest sensation in the area affected, while other forms of spontaneous sensation are comparatively uncommon. Occasionally, a feeling of numbness is felt in part of the segmental area in which the pain appears and sometimes at the same time as the pain. Sometimes a burning or a pricking sensation is felt in one leg or in the foot. Numbness or a burning pain is sometimes felt in the perineum. Numbness and tingling in one foot occurred in one case reported by Elsberg<sup>2</sup>. It is unusual, however, for the patient to be aware of any change in sensation. A cramping sensation sometimes occurs in one or both legs, and a feeling of fulness or of something in the rectum was present in one case.

(3) *Sphincter disturbances*.—Of the cases in which at operation or at autopsy a pure cauda equina lesion is found with no involvement of the conus or of the lumbosacral cord the sphincters are normal throughout in 34 per cent. In 50 per cent. of cases both bladder and bowel are affected at some time during the clinical course, the bladder alone being affected in 20 per cent. and the bowel alone in 2 per cent. Increased frequency of micturition is the initial symptom in 4.5 per cent.

A study of the sphincter disturbances in relation to the period of the clinical course reveals the following interesting information. In the early stages of the condition, in which is included the first half of the clinical course, retention of urine occurs in only 5 per cent., frequency of micturition in 4.5 per cent., while incontinence does not occur at all. During this stage, disturbance of the bowel in the form of constipation is present in less than 1 per cent.

During the second half of the clinical course sphincter disturbances occur much more frequently, frequency of micturition in 2 per cent., retention of urine in 41.5 per cent., and incontinence in 34 per cent. Constipation appears in 34 per cent., and lack of control of the bowel in 35 per cent. As for the bladder the usual sequence of events is frequency of micturition followed by or associated with retention of urine, and at a later stage by incontinence. With the bowel constipation usually precedes lack of control of the bowel movements. Nevertheless, as indicated above, disturbances of the sphincters are entirely absent in 34 per cent.

Reference to the anatomy and physiology of the nerves supplying the bladder shows that a pure caudal lesion can produce only two effects, viz., (1) interruption of the sacral autonomic path by involvement of the second and third sacral roots; (2) interruption of the afferent stimuli from the mucous membrane of the urethra. Physiologically, the sequence of events from involvement of these parts would be in turn (1) frequency of micturition; (2) retention of urine from paralysis of the detrusor with a slight degree of

automatic emptying of the bladder ; and finally (3) incontinence. A similar sequence of events might be expected in the bowel. From the small number of nerve roots to be involved and the habit of caudal tumours of involving some structures and missing others, it is apparent that the chances of the sphincters being implicated in the course of caudal tumours are no greater than that of involvement of any individual group of nerve fibres.

In one group of cases incontinence of urine and lack of control of the bladder appear early in the clinical course or comparatively suddenly after various symptoms have been present for a long period. In every one of these cases, either at operation or at autopsy it is found that the conus has been involved by the tumour ; so that it is reasonable to assume that, if these symptoms appear rapidly at any stage of the clinical course, it is probable that the conus has become involved. Such an accident means the difference in treatment and prognosis which depends upon dealing with a structure in which regeneration or functional recovery may be impossible and one in which they are possible. The rapid onset of such symptoms must, therefore, be regarded as a factor of grave importance in the prognosis of caudal tumours.

(4) *Motor disabilities*.—Weakness of the legs occurs as an initial symptom in 3 per cent. of cases and occasionally the clinical course is initiated by the rapid onset of paralysis of both legs. In about 30 per cent. of an average series of cases there is no motor disability whatever. In the remaining 60 per cent., it is practically always preceded by sensory symptoms and is frequently associated with disturbances of the sphincters. Usually the first complaint is of difficulty in walking or of weakness in one or both legs. Sometimes a history of local weakness is elicited, of weakness above or below the knee or of drop-foot. As a rule the difficulty in walking and the weakness of the legs become gradually worse. Occasionally the onset of motor symptoms is sudden and the legs become affected so rapidly that the patient is soon unable to stand or to walk. This is, however, somewhat unusual. In those cases in which the disability is confined to one group such as the muscles in the leg supplied by the sciatic nerve the weakness may not progress further.

Certain other motor symptoms are sometimes present. Spasm of the erector spinæ muscles and sometimes of the hamstrings has been described by Bennett<sup>19</sup>. Stiffness of the back is sometimes complained of by the patient. Cramps in the legs especially on going to sleep occur occasionally. Rarely some difficulty in walking is described but no associated weakness of the legs is found to account for it. Local wasting is rarely referred to by the patient, though on being questioned he may admit that one leg is smaller than the other or that both legs are getting thin.

(5) *Miscellaneous symptoms*. Loss of the power of erection and later of ejaculation usually appears late and apparently progresses *pari passu* with disturbances of the sphincters.

### V.—THE PHYSICAL SIGNS OF CAUDAL TUMOURS.

In cases examined during the period of onset the physical signs may be very scanty and special methods of examination including the investigation of the cerebrospinal fluid may be necessary in order to make or confirm a diagnosis of caudal tumour. In the average case which has reached the 'période d'état' the physical signs elicited may be grouped and described as follows :—(1) general abnormalities ; (2) changes in sensation ; (3) variations in the motor functions ; (4) variations in the reflexes ; (5) variations in the organic reflexes and associated functions ; (6) the results of X-ray examination ; (7) changes in the cerebrospinal fluid ; and (8) the results of special methods of investigation.

(1) *General Abnormalities*.—The most important of the general abnormalities are those associated with the vertebral column. The lumbosacral spine may be stiff and the erector spinæ muscles hard and firm. Flexion, extension and rotation of the spine may leave the lumbosacral portion quite immobile and produce an exacerbation of pain referred to an area in the lower limb. Pressure on the spine itself may elicit tenderness in the lumbar or sacral region and aggravate root pains already present in the lower limbs. Pressure on the top of the head may again produce local pain and exacerbation of root pains. Partial obliteration of the lumbar curve is present in some cases and may be due to a compensatory mechanism to relieve as far as possible the tension on the caudal roots. Ott and Adson<sup>4</sup> observed local tenderness of the spine in over one half of their cases. These signs are particularly important as they resemble very closely those elicited in local conditions of the lumbar muscles and of the lumbosacral spine.

(2) *Variations in Sensation*.—In about 23 per cent. of cases no objective sensory changes are found. Sometimes this may be so only in the early stages, but sometimes such changes are still absent when variations in the motor functions and the reflexes are fully developed. Such an apparent discrepancy between the motor and the sensory changes may often give a clue to the position of the tumour in relation to the caudal roots ; but, while occasionally in such cases the tumour is anteriorly placed, this is not always so. The remaining cases can be explained by the apparent habit of caudal tumours of involving some structures and leaving others unaffected.

In the great majority of cases the superficial sensations are affected and not the deep sensations. Of the cases reported in the literature tactile, thermal and pain sensibility was affected without involvement of the deep pressure and vibration sensation and the sense of position in 85 per cent. In a few cases tactile sensibility alone is affected, and in a few others tactile and pain sensibility alone. In an occasional case pain sensibility alone or pain and thermal sensibility together are affected ; but as a rule such findings are due to the fact that pain and thermal sensory abnormalities are more readily elicited and defined than are those of tactile sensibility. In only a rare case are pain and thermal sensation affected to the exclusion of variations in tactile sensation,

a finding which refutes the claim made by some writers that a dissociation of sensation of the syringomyelic type occurs in pure caudal lesions. Occasionally it is found that the areas of tactile, pain and thermal loss differ somewhat but not to any great extent, while the different types of sensation may be affected to different degrees. In the early stages the sensory changes may be slight and ill-defined; and as the condition develops all changes from slight loss to complete impairment may be encountered. As far as can be judged, the order in which superficial sensations are affected is probably tactile sensation first and thermal and pain sensation afterwards, though it is probable that in most cases all are more or less affected at the same time.

Variations in the deep sensations—deep pressure sense, vibration sense and the sense of position—apparently do not occur in the absence of variations in the superficial sensations, and in fact may be presumed to follow them. Once they are affected the variations in the deep sensations apparently proceed *pari passu* with those in the superficial sensations. In general, loss of vibration sense and of the sense of position appears to precede a loss of deep pressure sense, a sequence which has been suggested by Parker<sup>3</sup> as an important point in the differential diagnosis of caudal tumours and sacral *tabes dorsalis*. In many cases, objective changes in the sensations proceed *pari passu* with changes in the motor functions and in the sphincters, but to Parker's claim that this is usually the case we are unable to subscribe, as the position of the tumour in relation to the caudal roots and the character of the tumour itself lead to a pronounced discrepancy between the two groups of findings in more than one-third of the cases.

The sensory changes are usually found in the segmental area in which the pain occurs and in those adjacent to it. For example, it is common to find sensory changes in the first and second sacral segmental areas when pain is present down the back of the thigh and leg. Minor variations may be present in the segmental area immediately above and that immediately below that which is most affected, but the often quoted statement that the characteristic sensory changes occur chiefly in the third, fourth and fifth sacral areas (saddle anaesthesia) cannot be sustained. It is true that with pure sacral tumours the saddle area is often the first and only part affected and that when sensory changes are found in both lower limbs they may occur symmetrically in this area, but to state that it is the general rule is inaccurate. Probably such a generalisation had its origin in the artificial symptomatology deduced from the anatomy and physiology of the caudal roots, or in the practice of basing the recognised clinical features of caudal tumours entirely upon those of traumatic lesions of the cauda equina. Variations in sensation in the saddle area, even when they appear after sensory changes elsewhere, are found in less than one-third of the cases of caudal tumour. Asymmetrical changes in sensation are found in 60 per cent. of the cases. Symmetrical changes are more common when the abnormalities are found in either the upper or the lower sacral areas, that is in the feet or in the saddle area. In those cases with asymmetrical

changes, variations in one or more of the lower lumbar segmental areas are usually present and at a later stage the saddle area may become involved on both sides. Though theoretically tumours reaching a higher level than the sacral roots might be expected to produce extensive and possibly symmetrical changes, in practice this is not found to be the case. Involvement of the saddle area and symmetry would appear to be associated with low-placed tumours, while asymmetry with or without involvement of the saddle area would appear to be characteristic of high-placed tumours.

Occasionally the upper level of sensory loss is found to have some direct relation to the upper level of the tumour, but in the majority of cases this factor is an inaccurate guide.

In rare cases other sensory abnormalities may be present. Sometimes the margins of the anæsthetic areas are hyperæsthetic, as in one case reported by Parker<sup>3</sup>. Local tenderness of the lumbar spine and pain referred to one or both legs on palpation have already been mentioned. Pressure over the great sciatic nerve below the gluteal fold and even pressure on the external popliteal nerve behind the head of the fibula may elicit marked tenderness. Rarely paroxysms of pain are initiated by movements of the thighs or by pressure. These, however, have been reported in only one case, that described by Box<sup>27</sup>. The muscles of the lower limbs and especially of the calves are rarely tender to pressure; and very rarely flexion and extension of the knee produce pain in the distribution of the sciatic nerve.

(3) *Variations in the motor functions.*—Variations in the motor functions appear long after the subjective sensory changes. The time relation to objective sensory changes varies considerably. Sometimes they precede and sometimes they follow them. Frequently they are entirely absent. When present the segmental areas involved do not necessarily coincide with those in which sensation is affected. Sometimes they are at a higher level and sometimes at a lower level. The changes may appear on one side or on both sides. Occasionally they are symmetrical but more often they are asymmetrical. Most often there is weakness of an individual movement of one joint but no definite changes can be detected in one muscle or group of muscles. When more advanced there is paresis with atrophy and flaccidity in one group of muscles while those corresponding to the segments above and below are often weak. The group of muscles affected depends entirely upon the motor nerve roots involved. The group of muscles most often affected is the peroneal and less often the anterior tibial, resulting in each case in some degree of drop-foot and some weakness of dorsiflexion of the foot. Less commonly the posterior tibial muscles and the hamstrings are affected. Occasionally only the gluteal muscles on one or both sides are involved, leading to wasting over the sacrum and flattening of the gluteal fold and thus adding to the risks of a diagnostic error. Occasionally there is general weakness of one or both legs without any definite evidence of local paralysis. The quadriceps group is less commonly affected than are the other groups. When the tumour is placed low down in the



sacral canal the motor functions may escape entirely or the gluteal muscles alone may be affected. When several motor roots are involved there may be extensive flaccidity of one or both legs below the knee or of one or both lower limbs below the hip joint. Such extensive involvement of muscles is, however, exceedingly uncommon with caudal tumours. It is much more common for one or more segmental groups to be affected and for the others to escape.

Unusual features sometimes appear. Bennett<sup>19</sup> has reported a series of cases with spasm and contracture of the hamstring muscles associated with spasm of the erector spinæ muscles and rigidity of the spine. Fibrillary contractions are not uncommon in the affected muscles and a more or less definite reaction of degeneration may be present.

The gait varies considerably when the muscles are affected. Usually the patient walks weakly. However, when special groups are affected, certain characteristic types of gait are present. When the peroneal and anterior tibial groups are affected the gait may be of the steppage type. Sometimes it may appear to be definitely ataxic.

The importance of bilateral involvement of the motor functions in a case suspected to be one of caudal tumour cannot be underestimated, since in many cases of so called sciatica it may be the only clinical feature directly pointing to a lesion of the caudal roots. As an indication of the level of the lesion motor involvement has the same indefinite value as the subjective and objective sensory changes. The level of motor involvement may, however, indicate that the cauda equina has been affected at a higher level than is indicated by the changes in sensation.

(4) *Variations in the reflexes.*—The condition of individual reflexes in caudal tumours depends entirely upon whether the particular nerve fibres supplying the reflex are affected or not. In approximately 10 per. cent. of cases, including many in an advanced stage, the reflexes are entirely unaffected. Péron states that the reflexes in the sacral area are affected early, the ankle jerks and the hamstring reflexes being usually the first to disappear; and further that the knee jerks are usually present but are diminished or lost if the lesion spreads upwards. Similarly, current descriptions of the symptomatology of caudal tumours usually include the statement that the ankle-jerks are lost, the plantar reflexes give no response, while the knee-jerks and cremasteric reflexes are usually present. Such general statements are not supported by clinical experience. They take no account of the presence of lesions at a high level and of the fact that a tumour at a high level may involve one or more caudal roots and leave the others unaffected.

The reflexes are affected unilaterally or bilaterally according to the lateral position of the tumour. Frequently the changes are unilateral at first and become bilateral as the lesion extends. In an intermediate stage the changes are often asymmetrical but as motor and sensory changes in the lower limbs progress they are apt to be bilateral and symmetrical.

The first reflex to be affected depends entirely upon the caudal roots first involved. In the majority of cases an abnormality of the ankle jerk is noted first. One may be diminished or absent and the other remain normal; one absent and the other diminished, or both absent. In a minority of cases the knee-jerk may be affected first. One may be diminished or absent or both may be absent before the other reflexes are involved. Rarely one cremasteric reflex may be absent before the other reflexes are affected. In a case reported by Wallgren<sup>23</sup> both knee-jerks were absent and both ankle-jerks still present. In one of Bennett's<sup>19</sup> cases one knee-jerk was absent and the other reflexes unaffected in the early stages, while at a later stage both the knee- and ankle-jerks on that side were absent.

When one limb is affected the ankle- and the knee-jerks on that side may be absent together and the reflexes in the other limb unaffected. Occasionally in such a case the knee- and ankle-jerks in the opposite limb are exaggerated. Sometimes the ankle-jerk on one side and both knee-jerks are absent. In a case reported by Elsberg<sup>2</sup> both ankle-jerks were absent, both cremasteric reflexes absent, one knee-jerk diminished and the other exaggerated. At a later stage both ankle-jerks may be absent with absence of one or both knee-jerks, and finally both ankle- and both knee-jerks may be absent. In Ott and Adson's series of 12 cases the ankle-jerk was diminished or absent in 7 cases, and present or exaggerated in 5 cases. The knee-jerk was present or exaggerated in 7 cases and diminished or absent in 5 cases.

The superficial reflexes are often of additional value in indicating the level of the lesion. The plantar reflexes are either normal or result in no response. The latter may occur in the presence of cutaneous analgesia or of flaccidity of the muscles of the posterior compartment of the leg. The cremasteric reflex may be absent if the tumour affects caudal roots at the level of the second lumbar nerve-root. Thus the cremasteric reflex may help to localise the lesion at a higher level than is indicated by other symptoms or physical signs. In some of the cases reported the lower abdominal reflexes have been absent, but in view of the obvious difficulty of assessing the value of the loss of these reflexes on both sides especially in females and elderly patients it is difficult to draw any conclusion from this finding. Absence of the reflex on one side, however, may suggest that the lesion has reached a higher level than is suspected from the other symptoms and physical signs and thus be of considerable value in estimating the probable results of treatment.

In connection with the reflexes, as with motor and sensory functions, the roots both above and below the level of that involved may be unaffected, even though from the position of the tumour it might be expected that they would be. It is apparent, however, that the roots involved indicate that the upper level of the tumour has at least reached the level at which they leave the spinal canal, but that they may fail to give any indication of either its upper or lower limit because of the perpendicular course of the roots. In approximately half of the cases the upper limit of involvement of the reflexes gives an

indication of the level of the upper limit of the tumour, while in the remaining half the level of involvement of the reflex arc indicates a lower level, or the reflexes are entirely unaffected.

(5) *Trophic Disturbances*.—Trophic disturbances are present fairly often in the more advanced cases of caudal tumours. Atrophy of the affected muscles and the electrical reactions present have been referred to above. Congestion, dampness or coldness of one or both feet is sometimes present. Occasionally there is cedema of one or both feet. In one case there was massive, hard cedema extending up to a level just below the knees and presenting all the characteristics of the trophœdema usually associated with Milroy's disease.

Trophic sores may appear in the lumbosacral region or over the buttocks, and less often over the great trochanter or the heels. Such trophic sores are, however, present only in the few cases confined to bed in an advanced stage.

Cedema of the lower limbs was noted in two of Parker's cases, and Bailey has referred to a case described by Schmoll in which the cedema was so extensive that a laparotomy was performed to exclude a tumour pressing on the inferior vena cava.

(6) *X-ray Examination*.—X-ray examination of the lumbosacral spine is an essential part of the routine examination of all cases of suspected caudal tumour. In the majority of cases no abnormality whatever is detected. Occasionally evidence of absorption of the laminæ or of the bodies of the vertebræ is found and may indicate the effects of local pressure by a tumour within the spinal canal. In one case reported by Wolfsohn and Morrissey<sup>12</sup> there was cyst-like absorption of the posterior half of the bodies of the fourth and fifth lumbar vertebræ, while the laminæ were thin and hazy. At operation a large solid fibroma was found filling most of the spinal canal dorsal to the bodies of the fourth and fifth lumbar vertebræ. Occasionally evidence of malignant disease may be found in the bodies of the lumbar or sacral vertebræ.

Most commonly changes due to arthritis are found in the lumbosacral vertebræ. In some cases they may be enough to account for the symptoms, as in the group of cases described by Bailey and Casamajor<sup>29</sup>, but more often they render the final diagnosis more difficult. In one of Davies'<sup>30</sup> cases the X-ray findings characteristic of osteoarthritis added much to the difficulty of diagnosing a caudal tumour. In one of Elsberg's cases extensive arthritic changes were present in all the lumbar vertebræ, while in another there was spondylitis of the second and third lumbar vertebræ together with atrophy and thinning of the lumbar and upper sacral vertebræ. Apart from the increased difficulty in diagnosis which results from such findings, it is probable that if the causes of arthritis are active in the patient the condition is particularly apt to appear in a part whose resistance is lowered by the presence of a caudal tumour.

Congenital defects of the sacral spine may be found and spina bifida in particular. First described by Fuchs<sup>31,32</sup> under the name of myelodysplasia and subsequently elaborated by Lewandowsky<sup>33</sup>, Peritz<sup>34</sup>, Saenger<sup>35</sup> and

Spiller<sup>36</sup>, these defects are of considerable importance in diagnosis. In some cases the interpretation of X-ray findings may be exceedingly difficult. In one of Parker's<sup>3</sup> cases there appeared to be an area of decreased density in the first and second sacral vertebræ, possibly the result of pressure by a tumour, but at operation it was found that the changes were due to a spina bifida occulta involving the arches of the first and second sacral vertebræ. In one of Elsberg's cases a caudal tumour was associated with a defect in the middle line involving the first and second sacral vertebræ, which afterwards proved to be a spina bifida. Cushing and Ayer<sup>20</sup> reported an interesting case of anterior spina bifida associated with a caudal tumour, in which there was great difficulty in deciding what condition was responsible for the patient's symptoms and physical signs.

The more special methods of examination involving the use of X-rays are discussed later.

(7) *The Results of Lumbar Puncture.*—The clinical findings on lumbar puncture in the classical position fall into three main groups, viz., (a) failure to obtain fluid; (b) variations in the loculation syndrome; and (c) misleading findings.

A 'dry tap' resulted in 33 per cent. of the cases reported in the literature and in 6 out of Ott and Adson's 12 cases. In some cases no fluid is obtained on repeated punctures at the usual level and in other positions. The reason for the dry tap varies in different cases. In 60 per cent. of the cases of dry tap there was present in the spinal canal a 'giant tumour' of the type described by Collins and Elsberg<sup>37</sup>. In the remaining 40 per cent. the dry tap is the result of accidental insertion of the needle at the level occupied by the tumour. In the latter group of cases fluid is obtained by puncturing space by space above and below the site of the original puncture. Repeated dry taps by a skilled operator may be regarded as evidence that the spinal canal is probably occupied by a tumour; and occasionally the finding of fluid one or two spaces above the site of the original puncture is of value in fixing the upper level of the tumour.

The characteristics of the cerebrospinal fluid obtained below the lesion vary considerably. In only 13 per cent. of the cases recorded was it found to be normal. A normal cerebrospinal fluid is not necessarily associated with absence of definite physical signs confirming the presence of a caudal tumour. It is, however, the slight abnormalities in the cerebrospinal fluid of cases with an indefinite onset which help to confirm the presence of a caudal lesion. Recently, Elsberg and Constable<sup>16</sup> have expressed the opinion that with both extradural and intradural tumours of the cauda equina, whether a subarachnoid block can be demonstrated or not, the total protein of the cerebrospinal fluid is always found well above the normal. Nevertheless, their conclusion that a diagnosis of neoplasm in the lowermost part of the vertebral canal is not justified if the total protein is found to be within normal limits on lumbar puncture appears to be too dogmatic.

The fluid was yellow in 63 per cent. of the cases in which fluid was obtained by lumbar puncture from below the level of the tumour, while in two cases yellow fluid was found in an encapsulated space. The fluid varied in colour from a faint yellow colour to a deep golden yellow. In 29 per cent. the total protein or the globulin alone was increased without any change in the colour of the cerebrospinal fluid. In both the yellow and the colourless fluids the cells were within normal limits.

Misleading changes were found in a small proportion of cases. Occasionally 6 or 8 cells were present and less commonly as many as 25 or 28. In one case reported pus cells were present in the fluid for no obvious reason and in another 300 cells were present.

In one of Bennett's<sup>19</sup> cases there was removed in the lumen of the needle a small piece of tissue which on microscopical examination proved to be a piece of tumour. In some cases, even though no fluid was obtained, the impression was gained that the needle was passing through soft friable material.

In view of suggestions which have been made as to the source of the changes in the cerebrospinal fluid the cases in the literature were reviewed to determine the presence of any relationship between the nature of the tumour and its position and the changes in the fluid. There appears to be no relation between the type of tumour and the changes in the fluid. In 87 per cent. of cases in which marked changes are present the tumour is situated within the dural sac, but in the majority of cases in which the fluid is normal the tumour is also intradural.

In seven cases out of nine in which the examination was made pronounced changes have been found in the fluid above the level of the tumour. Such changes have been recorded on deliberate puncture above the tumour, on accidental puncture, at operation and on examination of the fluid from the cisterna magna. In the case of accidental puncture above the level of the tumour the changes may lead to the belief that the tumour is above the level at which the puncture is made, and in two cases reported by Cushing and Ayer<sup>20</sup> resulted in exploration of the spinal cord instead of the cauda equina. An equal amount of protein above and below the tumour has been reported in a case by Marie, Foix and Robert<sup>38</sup>, while in a further case described by Marie, Foix and Bouttier<sup>39</sup> it was suggested that the fluid above the tumour was abnormal. Ayer discussed the significance of different types of abnormal fluid from both the cisterna magna and the lumbar sac, and concluded that generally the increase in protein above the tumour was less than that below. No attention was, however, paid to the occurrence of an abnormal fluid above a tumour of the cauda equina until Cushing and Ayer's report of five cases in 1923. In Raven's<sup>40,41</sup> analysis of a series of cases of spinal tumour, a positive Nonne phase I reaction was described in one cerebrospinal fluid evidently obtained above a tumour of the cauda equina. The changes in the cerebrospinal fluid above the tumour in Cushing and Ayer's cases were similar to those below but less pronounced. In all five cases the fluid was yellow and the

protein in excess. Xanthochromia in the cisternal fluid was noted in one case, and also in a case reported by Hammes<sup>26</sup>.

Opinions differ as to the cause of the changes in the cerebrospinal fluid above and below the tumour. Ayer agrees with Sprunt and Walker's<sup>22</sup> opinion as to the significance of xanthochromia and regards the changes above, as below, to transudation from engorged veins, while Cushing believes them to be due to direct transudation from the tumour itself. In both cases it is believed that the fluid below becomes entrapped and thus concentrated, while that above escapes and becomes diluted. Cushing cites in support of his explanation the fact that in all of his cases the tumour was intradural. A review of the cases of caudal tumour described, however, shows that in 13 per cent. of those in which the fluid was abnormal the tumour was situated extradurally, and that in practically all the cases in which the fluid was normal the tumour was situated intradurally.

#### VI.—THE LOCALISATION OF CAUDAL TUMOURS.

The localisation of tumours of the cauda equina is often very difficult. The perpendicular course of the caudal roots within the spinal canal is the chief source of difficulty, for it is possible for a root to be involved in any position from the end of the spinal cord to its exit from the spinal canal. Hence from the signs of involvement of individual nerve roots it is impossible to determine the lower limit of the tumour. In many cases, however, it is possible from the study of signs of involvement of individual nerve roots to gain some idea of the position of the upper limit of the tumour. The following clinical features, when considered together, may give information of value: (1) pain in the back; (2) segmental pain in the lower limbs; (3) the upper limit of changes in sensation; (4) the level to which the reflexes are involved; (5) the level to which the motor functions are affected; and (6) the results of lumbar puncture. Cases occur in which it is impossible to localise the upper limit of the tumour. Each case has to be considered carefully on its merits, and it is only by so doing and by applying the results of past experience that some idea may be gained of the position, nature and extent of the tumour.

Pain in the back has been mentioned by Spiller<sup>15</sup> as a clinical factor of value in some cases. It has been shown, however, that the inaccuracy with which pain in this region is often described by the patient is usually a contra-indication to the use of the symptom in localisation. Cases occur, however, in which the pain is described with sufficient accuracy to indicate that the lesion has at least reached a certain level.

Nerve-root pains in the lower limbs would appear to be of greater value. A study of cases reported, however, shows that in only 10 per cent. of cases does the level of the root pain indicate the upper limit of the lesion. In rare cases it is of particular value. In a case reported by Lind and Lundstein<sup>22</sup> the pain was in the distribution of the second lumbar root and aton operati

a neurofibroma was found growing from the second lumbar posterior root. Localisation was possible in a similar way in cases described by Davies<sup>30</sup> and Elsberg<sup>2</sup>.

The level to which the different types of sensation are involved is occasionally of value, but again fails very often partly because anaesthesia and analgesia to a level corresponding to the upper limit of the lesion are usually a late manifestation. It has been shown that in approximately one half of the cases this sign alone indicates the upper limit of the lesion but that in the other half the lesion is usually at a higher level.

The level of motor involvement is as a rule of less value because of the difficulty of determining the upper level of muscular weakness. If a lumbar puncture results in a dry tap, a series of lumbar punctures from below up may eventually reveal the presence of fluid and show that the upper level of the lesion is below the level at which it was obtained.

It is found, however, that the best clinical method of determining the upper limit of the lesion is to take the uppermost of the upper levels of involvement as shown by the subjective and objective sensory changes, the changes in motor function and the variations in the reflexes. The latter are often helpful especially when one cremasteric reflex is absent and the other present. Occasionally a clue can be obtained to the lateral and antero-posterior position of the tumour. A preponderance of physical signs and even of subjective sensations on one side suggests that the tumour is placed rather to that side; while a preponderance of sensory signs over motor or vice versa suggests that the tumour is placed either behind or in front of the roots of the cauda equina. No general deductions can be made on such evidence though it is sometimes found to be useful in individual cases. Elsberg<sup>2</sup> has, however, pointed out that large soft tumours of the cauda equina which fill up the spinal canal are apt to produce largely motor symptoms and signs.

In early cases the only evidence suggesting the presence of an intraspinal tumour is the abnormality of the cerebrospinal fluid. A comparison of the fluids obtained by one or more lumbar punctures with that obtained by cisternal puncture sometimes reveals differences in the fluids at the different levels. An examination of the fluid from different levels above the tumour may reveal less colour or less protein at the higher levels. When lumbar puncture is performed below the tumour, the pressure of the fluid and the variations in the pressure with respiration and on superficial and deep jugular compression are less than those above. Ayer points out that if normal cisterno-lumbar pressure relations are obtained the tumour is probably below the site of lumbar puncture. Ayer and Mixter in particular have combined lumbar and cisternal puncture and consider that lumbar puncture alone is of little localising value. Cushing and Ayer<sup>30</sup> have used the following method to determine the presence or absence of a tumour in the lower part of the sacral canal. A needle connected with a manometer is inserted above the level of the suspected tumour and at the

same time 70 c.c. of saline injected into the epidural space through the sacral notch. Normally this injection produces a continuous rise of fluid in the manometer but in the presence of a tumour below the level of the upper needle this rise is very slight or absent.

A manoeuvre suggested by Viets<sup>28</sup> may help to determine the upper limit of the lesion. If lumbar puncture has been performed below the level of the block as indicated by the changes in the fluid, the comparison of the lumbar and the cisternal fluids and of the lumbar-cisternal pressure, and then the fluid is drained from below the block, jugular compression may produce intense pain in the segmental area corresponding to the uppermost root affected by the tumour. This manoeuvre has been reported in only one case, in which jugular compression after drainage of the cerebrospinal fluid from below the block produced pain in the upper part of the front of the thigh, disappearing on removal of the pressure. In this case a neurofibroma was found attached to the second right lumbar nerve root. Viets explains that by draining the fluid below the block the water-bed is removed and the collection of fluid above then acts as a buffer through which jugular compression exerts pressure on the tumour and produces traction on the nerve root.

Certain French workers have injected air corresponding to the amount of fluid removed and found that even when the block is only partial pain occurs in a nerve root area corresponding to the level of the tumour.

In some cases an accurate localisation may be possible only by the use of lipiodol according to the method introduced by Sicard. In the case of cisternal puncture lipiodol of high specific gravity is introduced and the level at which it is held up determined by X-ray examination. When a lumbar puncture is done below the level of the tumour lipiodol of low specific gravity may be introduced there and the lower limit of the tumour thus defined. Viets<sup>28</sup> has pointed out that shifting of the lipiodol shadow with changes in the position of the tumour is a characteristic feature of a caudal tumour free within the spinal canal and of particular importance in the differentiation of such a tumour from a tumour of the spinal cord or from one attached to the spinal meninges.

Recently Elsberg and Cramer<sup>43</sup> have pointed out that severe root pains and disturbances of the bladder have continued for some days and inflammatory changes have been found in the roots of the cauda equina after the use of iodized oil. In attempting to avoid these ill-effects they applied the method of multiple lumbar punctures used by Stookey and Klenke<sup>44</sup> to the localisation of tumours of the cauda equina. They found that it was possible to localise a tumour of the cauda equina and especially its upper and lower limits with some degree of certainty by this method. A failure to obtain fluid at any puncture indicated the presence of a giant tumour, while the demonstration of a complete or partial subarachnoid block by means of pressure readings at one level and not at another showed that the tumour was situated between the two levels, and the absence of a block at both the first and the fifth lumbar interspaces that it was probably situated in the sacral part of the lumbar canal.



## VII.—DIAGNOSIS AND DIFFERENTIAL DIAGNOSIS.

The general features upon which the diagnosis of a caudal tumour is based may be readily understood from the description of the symptoms and physical signs given above. This applies, however, to a more or less well-developed condition. Generally it may be accepted that if alterations in the subjective or objective sensory functions, motor functions or in the reflexes occur bilaterally the lesion responsible is in the spinal column or spinal canal if a lesion of the peripheral nerves can be excluded. Further investigations along the lines suggested above are then necessary to localise the lesion and, if it is found to be within the spinal canal itself, to determine its nature and position. Bilateral pain in the buttocks or in the distribution of the sciatic nerves, loss of both ankle jerks, wasting and sometimes fibrillation of muscles in both lower limbs and less often bilateral objective sensory changes are enough to suggest that the lesion is in the spinal canal or in the spine itself. It cannot be too strongly urged, however, that bilateral changes in any one of these groups alone is enough to give rise to the suspicion that a caudal tumour is present.

In the majority of cases, however, the symptoms and signs in the early stages are entirely unilateral. Frequently physical signs are entirely absent. Reference to the description of the initial symptoms shows that in over 90 per cent. of cases pain either in the back or referred to a root area in one or both lower limbs is the symptom which appears first. It is not always constant and may disappear only to reappear either in the same or in the other lower limb. In view of the gravity of caudal tumours diagnosed at a late stage it is important in all cases showing such symptoms to examine the cerebrospinal fluid in detail. In the event of a repeated dry tap or of changes in the fluid itself it is then necessary to apply the other methods described to confirm the presence or absence of a caudal lesion. In this connection the fact that minor changes in the cerebrospinal fluid sometimes occur in true sciatica does not in any way contra-indicate further investigation.

The sources of error in the diagnosis of caudal tumours in the early stages and the conditions from which they must be distinguished are numerous.

The differential diagnosis from unilateral or bilateral sciatic neuritis depends upon the thoroughness of the investigation, though in the latter case the chances are strong that the lesion is in the pelvis, spinal column or spinal canal. It must be recognised that many of the signs and symptoms of sciatic neuritis may be present with a tumour of the cauda equina. Pressure on the sciatic nerve in any part of its course may result in pain either locally or in the distribution of the sciatic nerve, there may be difficulty in extending the knee joint beyond ninety degrees without producing pain, Lasegue's sign may be present and the muscles may be tender to pressure. The presence of such findings may confirm an erroneous opinion that a condition with unilateral pain is sciatic neuritis and not a caudal lesion.

In multiple neuritis the widespread distribution of the disease, the characteristic sensory changes, the variations in the reflexes, the symmetrical

character of the clinical features and in most cases the absence of involvement of the sphincters serve to differentiate the two conditions. The form of amyotrophic lateral sclerosis in which the lower motor lesion affects the upper sacral segments sometimes causes confusion, but signs of the spastic element of the disease elsewhere or in the lower limbs usually suggest the nature of the condition. In both cases, whenever the diagnosis is in doubt, it is necessary to continue the special investigations until a caudal lesion is excluded.

Myositis, fibrositis, lumbago and other conditions which may bring the patient to an orthopaedic surgeon rather than to a neurologist may cause difficulty, again because of the ease with which the clinical features are ascribed to the muscles or fibrous tissues of the back. Bennett<sup>19</sup> has drawn attention particularly to spasm of the erector spinæ muscles and of the hamstrings together with rigidity of the lumbosacral portion of the spinal column in the early stages of caudal tumours.

Tumours within the pelvis must always be excluded especially when unilateral or bilateral pain is present. For this purpose a complete examination and exploration of the pelvis is often necessary.

Lesions of the spinal column itself often present the most serious problems in diagnosis. Spinal caries of tuberculous origin is stressed by Péron<sup>14</sup> as of particular importance in differential diagnosis, while secondary malignant disease of the vertebræ must also be considered. Both tuberculous and malignant conditions of the spinal column may reveal themselves initially as lesions of the cauda equina, but they are as a rule readily identified on X-ray examination and on consideration of the possible sites of tumours elsewhere.

Hypertrophic arthritis of the lumbosacral spine is readily identified on X-ray examination, which must be applied as a routine method of examination in these cases. Sacralisation of the fifth lumbar vertebra may sometimes result in damage to the fifth lumbar root on one or both sides and so produce pain, anæsthesia and motor weakness. Bailey and Casamajor have drawn attention to osteo-arthritis of the spine as a cause of compression of the spinal cord and its roots and Sachs and Fraenkel<sup>45</sup> in particular have described a case in which the clinical features resembled very closely those of a caudal tumour. It must not be forgotten, however, that the presence of these conditions does not necessarily exclude the diagnosis of a caudal tumour. The two conditions may quite well be present together and in that case a useful method of differentiating the lesion at the lower level from that at the higher level as the cause of the symptoms is to inject epidurally a solution of novocaine and to note the effect of the injection upon the pain.

The group of conditions collected by Fuchs<sup>21, 22</sup> under the name of myelodysplasia is often a source of difficulty and more especially the various modifications of spina bifida associated with some involvement of the caudal roots or even of the conus. In his original paper Fuchs described the clinical features as weakness of the sphincters and especially enuresis nocturna persisting after puberty, syndactylism, disturbances of sensation chiefly thermal and not

strictly segmental, particularly in the feet and toes, a defect in the sacral canal recognised on X-ray examination, anomalies in the cutaneous and tendon reflexes, and defects in the feet sometimes with weakness of the peroneal muscles and trophic and vasomotor disturbances. Mattanschek and Fuchs<sup>31</sup> found similar anomalies in 87 per cent. of adults with enuresis alone, and Peritz and Sachs in 68 per cent., while Saenger<sup>35</sup> found only one adult with myelodysplasia among patients with enuresis, and Vorkastner quoted Lewandowsky as stating that the conditions were merely associated. The absence of pain in such conditions, the long duration of the symptoms and the recognition of a defect in the sacral canal on X-ray examination often serve to differentiate the condition from a caudal tumour. It is obvious, however, that on these considerations the differentiation may fail completely. Spiller<sup>36</sup> has drawn attention to the fact that the condition may be entirely symptomless, and symptoms and physical signs appear only in adult life after violent exercise. In any case, just as with hypertrophic arthritis, the presence of spina bifida occulta does not exclude a diagnosis of caudal tumour. The two conditions were associated in cases reported by Parker<sup>3</sup>, Elsberg<sup>2</sup> and others. In one of Cushing and Ayer's<sup>20</sup> cases the diagnosis was for long in doubt because of the presence of an anterior spina bifida, a much rarer form of the condition. In addition, the thinning of the laminae of the vertebral arch or of the bodies of the vertebrae by pressure from a tumour may give the impression on X-ray examination that a spina bifida is present.

Neuritis of the cauda equina, cases of which have been described by Oppenheim<sup>46</sup>, by Kennedy, Elsberg and Lambert<sup>47</sup>, and by Reynolds<sup>48</sup>, is sometimes a source of difficulty. Such cases have usually come to operation and the diagnosis been made on exposure of the caudal roots. In all of the cases reported and in Parker's<sup>3</sup> case the diagnosis was made at operation and the caudal roots were found to be swollen, congested and matted together. Elsberg and Constable<sup>16</sup> recently contrasted the clinical features of a series of cases of neuritis of the cauda equina and of tumours of the cauda equina and dealt with the differential diagnosis in detail.

Meningoradiculitis involving the caudal roots, tuberculous or syphilitic in origin, and especially the sacral form of tabes dorsalis are as a rule readily excluded on examination of the patient, the cerebrospinal fluid and a blood Wassermann reaction. In connection with the former, however, it is important to note that in a few cases of caudal tumours the cell content of the cerebrospinal fluid has been increased for no obvious reason.

The differentiation of pure caudal tumours from those which involve the conus either primarily or secondarily is of particular importance when planning treatment and attempting to make a prognosis. A study of caudal tumours shows that those in which sudden and serious involvement of the sphincters has occurred either early or at any stage in the clinical course are found either at operation or at autopsy to have the conus implicated.

It may be extremely difficult to differentiate conditions involving the epiconus from caudal tumours. The epiconus syndrome as described by Minor<sup>49</sup> and revised by Alpers<sup>50</sup> consists of both positive and negative symptoms, the latter being quite as important as the former. The former are signs of involvement of the fifth lumbar and first and second sacral roots with absence of the ankle-jerk, while the latter consist of preservation of the knee-jerks and normal sphincters. While the outstanding feature is involvement of the peroneal muscles on both sides, the glutæi, hamstrings and extensors of the toes may be affected as well. In fact Seletzky<sup>51</sup> has suggested two types of epiconus syndromes, the first characterised by involvement of the glutæus maximus being due to a lesion of the lower part of the epiconus, and the second by peroneal paralysis due to a lesion of the upper part of the epiconus. Cases have been described in injury of the spinal cord by Minor and by Weisenburg<sup>52</sup>, in poliomyelitis by Minor<sup>53</sup> and by Spiller<sup>54</sup>, in spina bifida occulta by Tutyshkin<sup>55</sup>, in tabes dorsalis by Alpers, as the result of an infiltrating tumour by Ornstein<sup>56</sup>, and also by Parker<sup>3</sup> and Levison<sup>57</sup>. It may occur as a result of traumatic myelitis, of myelitis due to other conditions, and of myelomalacia from vascular degeneration and thrombosis. The absence of pain is rarely of value in differentiation especially as pain may occur in an anæsthetic area with an epiconus lesion. The order in which the symptoms and physical signs appear together with a strong tendency to asymmetry in caudal tumours is often of value in differential diagnosis.

It might not be thought that tumours of the spinal cord itself would present any difficulties in diagnosis. Sargent<sup>58</sup> has, however, drawn attention to the occurrence of what appear to be root pains in the lower limbs in some cases of spinal cord tumour, possibly as a result of pressure upon selected pain fibres in the lateral column of the spinal cord. In such cases, however, a complete neurological examination is usually enough to enable one to decide that the symptoms are those of a lesion at a higher level than that of a caudal tumour.

### VIII.—DISCUSSION.

A review of the clinical features of tumours of the cauda equina reveals many points which are of value in the study of an individual case, and shows that certain general principles often applied to the study of caudal tumours have no actual foundation in experience.

The symptomatology of caudal tumours cannot be assumed from the anatomical and physiological functions of the parts which form the cauda equina. Nor can they be assumed from a study of the traumatic lesions of the cauda equina. It is evident that the application of the general principles obtained by a study of the anatomical and physiological features and of traumatic lesions will result in the diagnosis of caudal tumours in many cases only when treatment is of no avail. If the object of the investigation of the patient is to be the successful treatment of the condition from which he suffers, which is

possible only if the condition is diagnosed in its early stages, some more satisfactory basis must be found for the investigation of such lesions.

It is necessary to separate the symptomatology of tumours of the cauda equina itself from those due to involvement of the conus in addition to the cauda equina. In order to do this it is essential to define pure caudal tumours as those entirely below the lower border of the second lumbar vertebra. Having done this the significance of disturbances of the sphincters is at once apparent. The late and gradual appearance of sphincter disturbances then becomes apparent as a feature of caudal tumours, whereas the rapid appearance of sphincter disturbances at an early stage or at any part of the clinical course would appear to indicate that a purely caudal tumour has become complicated by involvement of the conus.

The habits of a caudal tumour in regard to its symptoms, physical signs and clinical course cannot be compared with the clinical picture produced by experimental or accidental injury to the cauda equina. A tumour in this region, even when very extensive, appears to follow no general rules in regard to the structures it involves. Hence some structures are affected and others unaffected for no obvious reason. The symptoms and the physical signs vary in consequence.

The importance of the recognition of the initial symptoms and of the value of pain as a symptom has been established. The influence of the recumbent position and of movement on the pain in the early stages is an important diagnostic feature. Pain in the back would appear to be of greater value in drawing attention to the condition than pain confined to a segmental area in one lower limb. This finding has the obvious corollary that cases of chronic pain in the back and in the sacral region must be investigated as carefully for evidence of a cauda equina tumour as are those of sciatica. Another point of importance which has emerged from this study is the frequency of intermissions in the pain before the appearance of physical signs upon which a tumour of the cauda equina might be suspected on clinical evidence alone. The intermissions appear to vary in duration according to the rate of involvement of the cauda equina, lasting from three months to as long as seven years. The second attack of pain may not be in the same position as during the original attack. One attack of sciatica followed by a second attack in the other lower limb after an interval of one or two years does not necessarily mean two attacks of sciatica; it may be an indication of the bilateral distribution of symptoms upon which the presence of a caudal tumour is usually suspected.

It is evident, however, that in the early stage and especially when pain is the most prominent symptom, a diagnosis of a caudal tumour cannot be made even on a complete neurological examination. It is necessary to introduce special methods of investigation, of which lumbar puncture appears to be the most important. The need of attempting to obtain and examine the cerebrospinal fluid in every case of persistent pain in the back, in the sacral region, in a segmental area or even in a part of a segmental area is established. The

importance of a repeated dry tap is evident and the significance of slight changes in the cerebrospinal fluid must be emphasised. In the presence of such minor indications the value of X-ray examination of the spine and of further attempts to localise the lesion by means of multiple lumbar punctures or lipiodol cannot be under-estimated. The significance of pain during the 'période de début' is interpreted erroneously in nine cases out of ten when the investigation is confined to the usual clinical procedures.

When physical signs appear they are often in the first place asymmetrical. Any evidence of the bilateral distribution of symptoms and physical signs, whether it be in regard to subjective sensations, objective sensory changes, changes in the reflexes, or alterations in motor function, should and in fact usually does lead to the suspicion that a lesion exists at the level of the exit of the nerves from the spinal canal or at a higher level. Here again detailed investigation is essential. The importance of studying such changes on first principles as evidence of involvement of individual nerve roots must be recognised so that the nature and position of the lesion may be determined. Evidence of involvement of some caudal roots and of the sparing of others is particularly valuable in the diagnosis of caudal tumours at an early stage.

It may be accepted that the physical signs of caudal tumours at the stage when a diagnosis may be made on clinical findings alone do not necessarily follow any definite type. It is only in the later stages that the clinical picture can be said to conform to a type or to resemble in any way the clinical descriptions.

The importance of abnormalities of the cerebrospinal fluid has been confirmed and in addition the source of error due to changes in the fluid above the tumour has been emphasised.

Accurate localisation of the tumour is necessary for the most successful treatment. The upper limit can probably be determined more or less accurately in some cases by a careful study of the symptoms and physical signs. In the majority of cases in which physical signs are present this method results in an approximate localisation. The lower limit can sometimes be determined by multiple lumbar punctures or by the introduction of lipiodol of low specific gravity below the tumour. The lateral position of the tumour may sometimes be assumed from the more or less unilateral distribution of the symptoms and physical signs, and the antero-posterior position from the relative preponderance of symptoms and signs of involvement of motor or of sensory roots. The latter generalisation is, however, subject to the difficulty that giant tumours of the cauda equina may involve motor roots to the entire exclusion of sensory roots.

The differential diagnosis of caudal tumours depends upon a careful and detailed investigation of the patient. Occasionally sources of difficulty arise, as in the not uncommon association of hypertrophic arthritis of the spine or of spina bifida occulta with the lesions under consideration. In such cases the

chances of confusion are lessened by assuming that the clinical picture is the result of the more serious condition and carrying the investigation of the patient further until this is proved or disproved.

#### IX.—SUMMARY AND CONCLUSIONS.

1. This paper is based on a review of the clinical features of cases of tumour of the cauda equina, and confined to the study of those in which the presence, nature and position of the tumour have been established either at operation or at autopsy.

2. The successful study of tumours of the cauda equina depends upon the separation of those in which the cauda equina alone is involved from those in which the conus and the structures above it are involved in addition to the cauda equina.

3. The various methods of approach to the study of the clinical features of tumours of the cauda equina are considered in detail. With the exception of the 'hemicaudal' and 'radicular' syndromes of Roussy and Lhermitte none of them appears to offer a satisfactory basis for the study of such lesions. The only feasible method appears to be the study of the clinical features on the basis of the evidence of involvement of individual nerve-roots and the interpretation of the findings so made in the light of experience of the clinical features of tumours of the cauda equina.

4. The clinical course of tumours of the cauda equina is reviewed, the results of treatment at different stages studied and the conclusion reached that successful treatment must depend upon the diagnosis of the condition in its early stages.

5. The importance of pain as the initial symptom is confirmed, and emphasis laid on the fact that pain in the back may be a more common initial symptom than segmental pain in the lower limb.

6. The clinical features of tumours of the cauda equina are discussed in detail and the conclusion reached that it is only in the well-developed case that any particular type of clinical picture is found. Important points would, however, appear to be the asymmetrical character of the clinical findings and the appearance of changes bilaterally in one or more of subjective sensations, objective sensations, motor functions and reflexes.

7. The stage of onset is the stage of diagnostic errors. If investigation is confined to ordinary clinical methods at this stage such a position is inevitable. Consequently special methods of examination and especially a detailed examination of the cerebrospinal fluid are essential.

8. When one or more physical signs are established the bilateral distribution of any of them is suggestive and further investigations may then be necessary to confirm the diagnosis and to localise the lesion.

9. The tendency of tumours of the cauda equina to affect the nerve roots in a haphazard manner is mentioned and emphasis laid upon the effect of this

characteristic in making it impossible to study such tumours according to the clinical descriptions of traumatic lesions of the cauda equina or according to recognised syndromes.

10. The delay in investigation and the postponement of surgical treatment until a clearcut type of clinical picture is present means in most cases waiting until the condition is beyond the resources of treatment.

11. The various conditions with which tumours of the cauda equina may be confused are mentioned and emphasis laid upon possible sources of confusion in differential diagnosis.

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